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# A report on some specific features of the atmospheric electric potential gradient in Kolkata

S S De[*1], B K De[2], S K Adhikari[1], S K Sarkar[3], R Bera[1], A Guha[1] and P K Mandal[1]

[1] Centre of Advanced Study in Radio Physics and Electronics, University of Calcutta, 92, A. P. C Road, Kolkata - 700 009, India

[2] Department of Physics, Tripura University, Agartala, Suriyamaninagar - 799 130, Tripura, India

[3] Department of Physics, University of Calcutta, 92, A P C Road, Kolkata - 700 009, India

E-mail de_syam_sundar@yahoo.co.in

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**Abstract** : The results of measurement of surface potential gradient of the atmosphere in Kolkata (latitude 22°34′ N) will be presented The observed fields at daytime and night time are seen to be higher and show considerable fluctuations from the daily averages of electric field and also a few hours difference in phase with the observations made at different tropical and temperate latitudes. The mean value of the potential gradient averaged for 35 days over a period from February 2004 to January 2005 is around 200 $Vm^{-1}$ and the maximum and minimum values are 1 14 times and 0 88 times the mean value, respectively. The results are discussed in terms of the variations of the local factors as well as distribution of thunderstorm activities.

**Keywords** Atmospheric electricity, potential gradient, global electric field, thunderstorm activity

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## 1. Introduction

Electric field at a point on the earth's surface depends on the major thunderstorm activity of the globe and on the local environmental factors. There exists a correlation between the local electric field and worldwide thunderstorm distribution.

Various models for thundercloud electric field have been developed to investigate their behaviour into the region between the surface of the earth and the upper atmosphere [1-3].

Also, there are models for the determination of electromagnetic fields and charge distribution during lightning [4, 5]. The surface-air temperature variations both at tropical latitudes (± 25$^0$) and temperate latitudes (± 60$^0$) and its upward trend [6, 7] are found to be very much interrelated with the global lightning activity [8]. Such analysis could monitor the lightning activity over the global atmosphere.

Global weather activity maintains a potential difference of about 250 KV between earth-ionosphere waveguide, which generates a potential gradient of about 120 $Vm^{-1}$ at the earth's surface. A vertical conduction current is maintained due to the finite conductivity of air resulting in a DC global circuit. Electric field intensity undergoes diurnal and seasonal fluctuations and found to be greater at the northern hemisphere during winter than in the summer. During fair weather electricity, there would be no process of charge separation taking place in the atmosphere and the electrical phenomena are reasonably steady [9]. Within such fair-weather condition (quasi-static state), electric field, current density and conductivity over the surface of the earth are subjected to both global and local variations. Global variations are associated mainly with tropical thunderstorms.

The production of high potential difference between the earth and the ionosphere due to the total number of thunderclouds acting together at any time, drives the air-earth current downward from the lower region of the ionosphere to the surface of the earth in the fair-weather region. This current in the nonpolluted areas varies in accordance with the ionospheric potential and columnar resistance, while in the polluted areas, due to the high aerosol content in the lower layer of the atmosphere, the columnar resistance increases [10].

* Corresponding Author

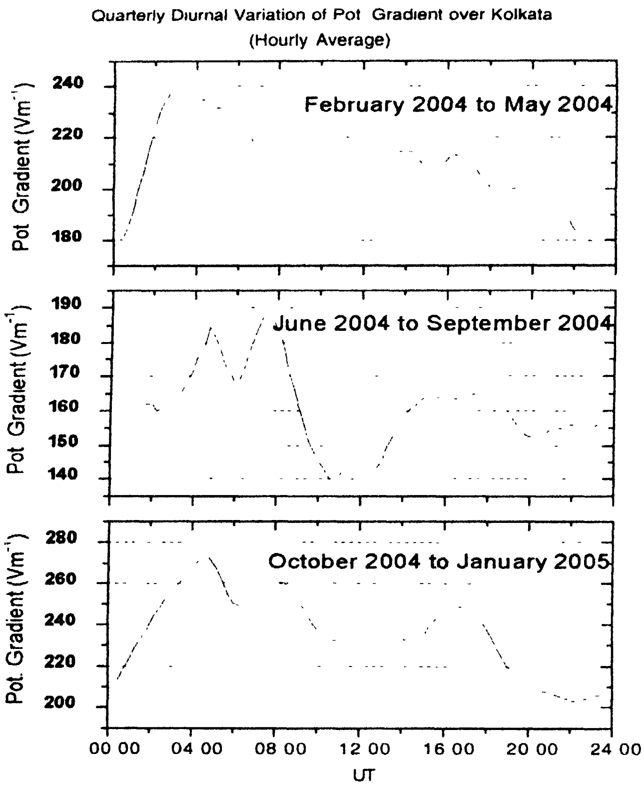


**Figure 6.** Quarterly diurnal variation of potential gradient over Kolkata

2004 and January 2005 [Figure 8]. The analysis shows that the rms fluctuation in our measurements is around 33%.

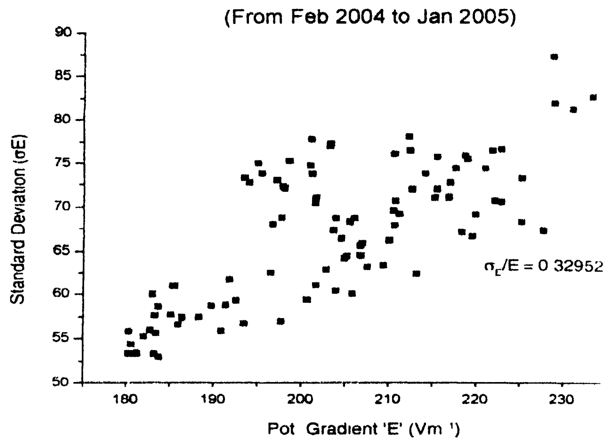


**Figure 8.** Plot of yearly mean values of RMS fluctuation of the potential gradient

Figure 9 shows the variation of rms fluctuation ($\sigma_E/E$) with respect to universal time. It is clear that the rms fluctuation is maximum around 0400 UT and 1000 UT and it is minimum around 0700 UT and 1900 UT.

We calculated the area under each diurnal variation of every month and plotted the percentage variation in Figure 10. Each bar represents atmospheric activity with respect to vertical potential gradient in Kolkata. It is clear that in winter seasons the potential gradient becomes higher compared to Monsoon season.

Additionally, the observed average diurnal variation of the potential gradient (as shown in Figure 2) is much different phase and amplitude from the universal value. The peak observed at 16 UT is about 3 hr earlier in phase than predicted under the world-wide thunderstorm activity. The amplitudes of the diurnal variation are much larger in our observations than the result obtained by other workers [12-16].

The variations of the potential gradient presented in different records, follow mostly the general trend of fluctuations

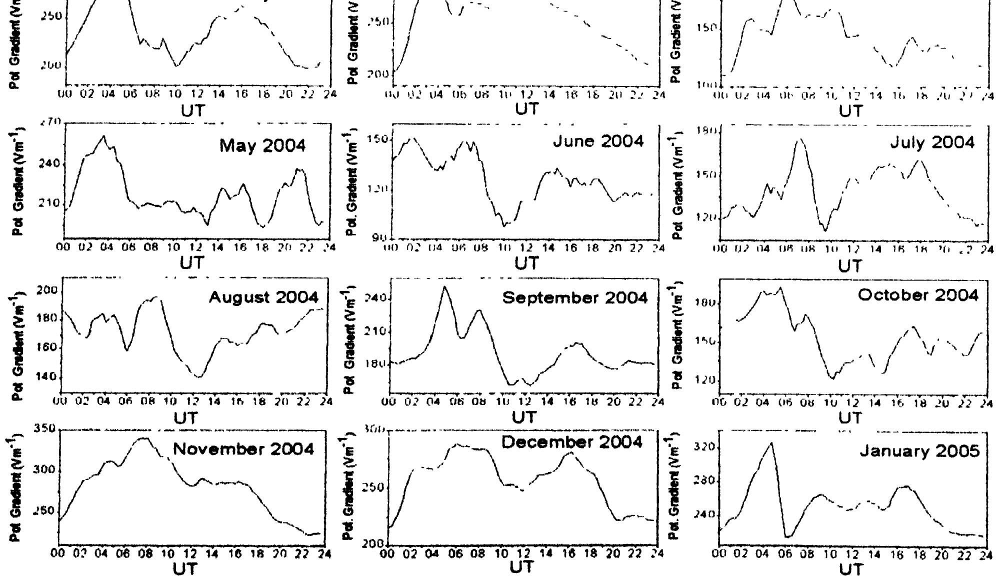


**Figure 7.** Monthly diurnal variation of potential gradient over Kolkata.

excepting that the results are interrogated by local effects other than the global reasonings. The high value obtained as a consequence of the poor value of conductivity of the air at the earth's surface in Kolkata. It is due to the presence of excessive pollutant particles (7 x $10^3$ -1.15 x $10^4$) per c.c. [data obtained from Indian Meteorological Department by private communication], containing aerosols, aitken nuclei, $CO_2$ from fossil fuel *etc.*, which reduce the mobility of the atmospheric constituents [14].

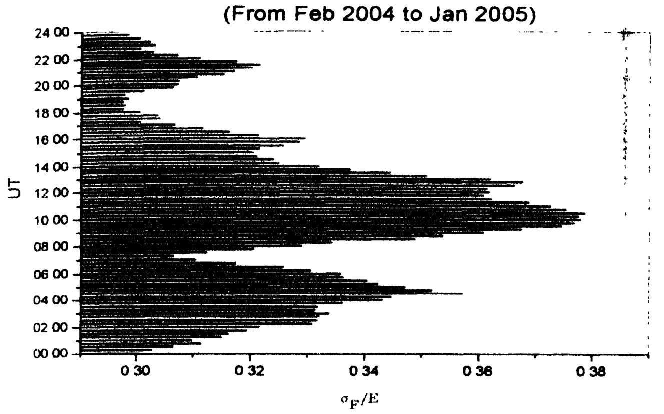


**Figure 9.** Plot of yearly mean diurnal fluctuation of RMS fluctuation of the potential gradient

## 4. Pollutants and their effects on local electric potential gradient

Kolkata is a densely populated city, surrounded by small and large-scale industries. Air is greatly invaded by pollutant particles emitted from many types of industries. Thus, Kolkata falls under small-scale fair weather condition where fluctuation of electric field and air-earth current are perturbed by ionization and different aerosols which are produced locally [9]. Fine particles having diameter less than 0.1 $\mu$m (Aitken nuclei), are

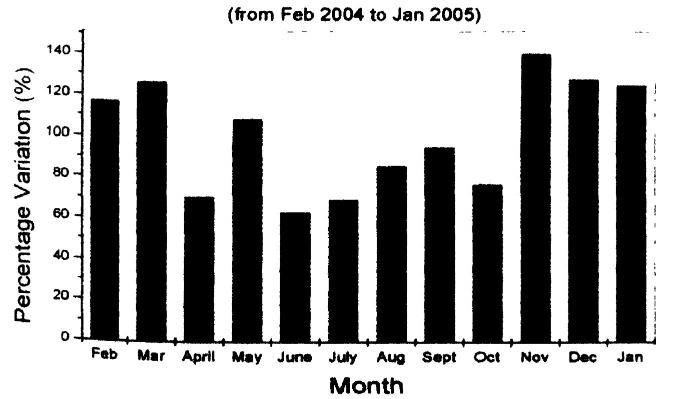


**Figure 10.** Plot of monthly percentage variation of atmospheric activity deduced from integration of diurnal variation of the potential gradient of each month.

distributed in air, which lower the conductivity and increases the columnar resistance [17]. The atmospheric turbulence forces the positive space charges to higher altitudes against the forces of the existing electric field. This generator effect of the turbulence, affects the atmospheric electric field and current locally. The aerosol particles in the industrial area of Kolkata steadily changes their status at different times of the day by coagulation, sedimentation, charge transfer, initiated by the local physics of precipitation. Industrial activity injects the particulate matter into the atmosphere [15].

It is found that the diurnal variations of potential gradients in Kolkata near town areas are caused mainly by urbanization, industry and traffic. The atmospheric suspensions, known as Haze, are mostly present to the lower layers of the atmosphere [18]. The rate of production and vertical transport of pollutant particles determine the daily variation of atmospheric pollution.

Ions strongly influence the electrical conductivity of the atmosphere. If aerosols, such as cloud or fog droplets, haze or pollution particles are present, small ions attached to them, form 'large ions', thereby reducing their mobility and the atmospheric conductivity. Thus, one of the possible reasons of high value of the potential gradient over Kolkata is due to the poor value of the electrical conductivity of the atmosphere. Pollutant particles due to smokes from combustion processes (domestic and industrial origin), reaction of natural and anthropogenic gaseous species, wind blown dusts reduce the conductivity [19]. Aerosol particles (composed of combustion products and soil particles), which are smaller than 5$\mu$m in diameter, tend to form more stable suspension in air [20, 21]. The presence of nuclei (pollution particles artificial or natural) may combine with ions and decrease the concentration of, or immobilize the small ions, hereby the conductivity is reduced. It is very common with Aitken nuclei (smoke with about 0.1 $\mu$m diameter) due to which local electric field increase [22, 23]. The influence of fossil fuels ($CO_2$ emission) within the pollutants is also responsible for high value of electric field. The variation of energy consumption of traffic (oil and gasoline) in Kolkata would contribute to a high Aitken count and there are changes in atmospheric dispersion that reduce the conductivity of the medium.

Moreover, differential heating by solar radiations may lead to convection and redistribution of small ions and hence, decrease the effective conductivity of the air which is supportive to higher potential gradient.

## 5. Discussion

It is thus clear that the worldwide thunderstorm activity is not a direct factor affecting the electric field in Kolkata. The peak observed at 16 UT is about 3 hours earlier than the predicted worldwide thunderstorm activity, although the value is typically quite higher as described. Some measurements show temperature inversion conditions that influenced the diurnal behaviour of the electric field.

The atmospheric electric field is expressed as $E = V/\lambda R$, where $V$ is the potential difference from the lower level of the ionosphere to the earth's surface, $\lambda$ is the conductivity of the air and $R$ is the columnar resistance. For fair weather, $V$ and $R$ change very little. $E$ is then controlled mainly by $\lambda$ and those parameters upon which $\lambda$ depends. Thus, the local conductivity can vary over a considerable range without introducing a significant change in the columnar resistance. Because of various parameters on the land surface influencing the conductivity value, land measurements are not suitable to study global effects. Of course, fair weather measurements made over clean places like oceanic surfaces, high mountains, represent global effects and have been made useful for investigating the behaviour of global electric circuit.

Although the results presented here are mostly influenced by local effects giving much higher diurnal values of atmospheric potential gradients, these are in accordance with the trend of variation of potential gradient measured at the tropical ocean, the Bay of Bengal followed by certain lead in phase and amplitude [24]. In their field curve of 40 days measurements, a maximum around 10 UT and a small secondary peak at 1900 UT occur, while the observation of 35 days average over Kolkata depicts the maximum at 0500 UT with a secondary peak at 1600 UT followed by the phase lead by 3 hours from the measurement in Indian Ocean, Bay of Bengal and Arabian Sea. The observed phase lead may be due to the local influence in the atmosphere over Kolkata. Moreover, our results also indicate a tendency to manifest the thunderstorm activity over Asia-Australia region which becomes maximum at 0800 UT. It is worthwhile to mention that the measurement at Asiatic tropical zones exhibit the resemblance of peak thunderstorm activity at 0800 UT of Asia-Australia region. So apart from local influences, in a tropical region, continental thunderstorm activity plays an important role in modulating the global electric circuit.

To explore regional thunderstorm activities and their effects on the global electric circuit, the data of atmospheric conductivity, Maxwell current and Schumann resonance phenomenon would be helpful along with the vertical potential gradient. Simultaneous measurements of the above mentioned parameters at different latitudes would definitely help in understanding global as well as regional thunderstorm activities. It will allow critical re-examining of certain parameters of atmospheric electricity which have served as *de facto* standards of global electric circuit.

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